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NEW SPACE OF DIGITAL IMAGES AS LEARNING TOOLS

NOVO ESPAÇO DE IMAGENS DIGITAIS COMO FERRAMENTAS DE APRENDIZAGEM

NUEVO ESPACIO DE IMÁGENES DIGITALES COMO HERRAMIENTAS DE APRENDIZAJE

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Abstract

Digital images are used in image processing, a growing application area in many scientific disciplines. In Linear Algebra, digital images can be used for more meaningful and motivating learning by engineering students. A new digital imaging space as a learning tool has been developed over the last five years, establishing an interaction between digital learning resources and the curriculum, while providing personalized learning opportunities. Students of two engineering degrees at the Coimbra Institute of Engineering use this learning tool in laboratory classes as a complement.

The purpose of this paper is to present some experiences developed by students within the scope of two Linear Algebra courses that use the new space of digital images specifically to support learning. In this space, students use digital images as a methodology for learning the syllabus and associated mathematical skills. Six experiments were carried out and the results are presented and discussed, highlighting the contribution of this type of methodology as a significant support in the teaching and learning of mathematics for engineers. Learning in this space, and due to the use of recent technologies, becomes effective and stimulating for the students and the teacher manages to "enchant" his/her students in the teaching-learning process.

Keywords: digital image, learning tools, active learning, image processing, mathematics.

Resumo

As imagens digitais são usadas no processamento de imagens, uma área de aplicação crescente em muitas disciplinas científicas. Na Álgebra Linear, as imagens digitais podem ser usadas para uma aprendizagem mais significativa e motivadora dos alunos de engenharia. Um novo espaço de imagem digital como ferramenta de aprendizagem foi desenvolvido nos últimos cinco anos, estabelecendo uma interação entre os recursos digitais de aprendizagem e o currículo, ao mesmo tempo em que oferece oportunidades de aprendizagem personalizadas. Os alunos dos dois cursos de engenharia do Instituto Superior de Engenharia de Coimbra utilizam esta ferramenta de aprendizagem nas aulas laboratoriais como complemento.

O objetivo deste artigo é apresentar algumas experiências desenvolvidas por alunos no âmbito de dois cursos de Álgebra Linear que utilizam o novo espaço das imagens digitais especificamente para apoiar a aprendizagem. Neste espaço, os alunos utilizam as imagens digitais como metodologia de aprendizagem dos conteúdos programáticos e competências matemáticas associadas. Seis experiências foram realizados e os resultados são apresentados e discutidos, destacando a contribuição desse tipo de metodologia como um suporte significativo no ensino e aprendizagem da matemática para engenheiros. Aprender neste

espaço, e devido ao uso de tecnologias recentes, torna-se eficaz e estimulante para os alunos e o professor consegue "encantar" seus alunos no processo de ensino-aprendizagem.

Palavras-chave: imagem digital, ferramentas de aprendizagem, aprendizagem ativa, processamento de imagem, matemática.

Resumen

Las imágenes digitales se utilizan en el procesamiento de imágenes, un área de aplicación en crecimiento en muchas disciplinas científicas. En álgebra lineal, las imágenes digitales se pueden utilizar para un aprendizaje más significativo y motivador por parte de los estudiantes de ingeniería. En los últimos cinco años se ha desarrollado un nuevo espacio de imágenes digitales como herramienta de aprendizaje, que establece una interacción entre los recursos de aprendizaje digital y el plan de estudios al tiempo que brinda oportunidades de aprendizaje personalizadas. Los estudiantes de los dos cursos de ingeniería del Instituto Superior de Engenharia de Coimbra utilizan esta herramienta de aprendizaje en las clases de laboratorio como complemento.

El objetivo de este artículo es presentar algunas experiencias desarrolladas por estudiantes dentro de dos cursos de Álgebra Lineal que utilizan el nuevo espacio de imágenes digitales específicamente para apoyar el aprendizaje. En este espacio, los estudiantes utilizan imágenes digitales como metodología para el aprendizaje del temario y las habilidades matemáticas asociadas. Se realizaron seis experimentos y se presentan y discuten los resultados, destacando el aporte de este tipo de metodología como un apoyo significativo en la enseñanza y aprendizaje de las matemáticas para ingenieros. El aprendizaje en este espacio, y debido al uso de las últimas tecnologías, se vuelve efectivo y estimulante para los estudiantes y el docente logra “encantar” a sus alumnos en el proceso de enseñanza-aprendizaje.

Palabras clave: imagen digital, herramientas de aprendizaje, aprendizaje activo, procesamiento de imágenes, matemáticas.

INTRODUCTION

Engineering students are students who like to learn by doing. They like to understand the usefulness of what they learn and where they can use that learning (Pantzos, 2023). Active learning is a learning that motivates and challenges students, using real and imagined situations in which students engage in higher order thinking tasks, such as analysis, synthesis, and evaluation (Lima, 2017, Raveendranath, 2022).

Image processing consists of successively transforming a digital image with the aim of extracting the information present in it more easily (Zhang, 2021). The quantitative analysis and interpretation of images currently represents an important area in several scientific disciplines. Image processing techniques are based on mathematical methods that allow quantitatively describing of images, hence being an educational tool for learning mathematics, particularly in Linear Algebra.

With the aim of motivating and involving the engineering students, allowing them to achieve meaningful learning, in a Linear Algebra curricular unit of two engineering degrees, learning tools in digital environments have been used (Wallach, 2022). Following the work developed and presented by Caridade (Caridade, 2021), this paper describes the new space for digital images such as learning tools and their relationship with the skills acquired by students. In this new learning space, students were challenged to develop six different types of experiences.

METHODOLOGY

In the last five years, in Linear Algebra classes, teaching-learning experiences have been developed using digital images. Students of Electromechanical and Biomedical Engineering of Coimbra Institute of

Engineering, in laboratory classes, learn the concepts of Linear Algebra through digital images. Definitions, properties, concepts, and theorems are learned with everyday images exploring and working with Linear Algebra contents. In laboratory classes, students apply some experiences using Matlab, to make learning more meaningful and motivating.

EXPERIENCES IN NEW SPACE

A digital image can be seen as a function f from N^d to R^B that associates to each discrete coordinate $(m, n, \dots) \in N^d$ a finite set of intensities $\{i_1, \dots, i_B\} \in R^B$:

$$\begin{aligned} f: \quad & N^d \rightarrow R^B \\ & m, n, \dots \rightarrow f(m, n, \dots) = \{i_1, \dots, i_B\}. \end{aligned}$$

A digital image can also be seen as an array of d dimensions whose elements contain B numbers. For example, a grayscale image corresponds to $d = 2$ (the image has two dimensions) and $B = 1$ (there is only one value per location (m, n) – the grayscale intensity); a common colour image corresponds to $d = 2$ and $B = 3$ (3 bands, typically red, green, and blue). In this sense, working with digital images corresponds to working with matrices, which allows the construction of Linear Algebra learning in a differentiated, motivating way and in a real context. Thus, the new space of digital images was created as a learning tool. In this paper, some examples developed by the students in this space will be presented, where the connection between the digital image and Linear Algebra is present.

In the first experience, represented in Figure 1, on the left images A and B are shown in colour (first line), grayscale (second line) and white and black (third line). In this example, the student can identify the dimensions of a matrix, the type of matrix and its relationship with digital images. Operations with matrices and their properties can be explored through images. The definition of 2D or 3D matrix, identification of specific elements of the matrix, basic operations, and its properties such as commutativity and associativity can be learned through two digital images. In Figure 1 on the right, some of these concepts are presented. The two images C and D were subjected to several operations such as multiplication (CxD), addition (C+D), subtraction (C-D), scalar multiplication (kC and kD), and transpose (C^t and D^t).

In grayscale or black and white images in 2D space or color images in 3D, the properties of basic operations between matrices can be observed. The example shown in Figure 2 involves solving the matrix equation $(4X)^t - A = 2B$ using the properties of matrix addition, matrix scalar multiplication, and matrix transpose. In this specific case, it is necessary to find the X matrix, i. e., the image on the right of Figure 2.

Figure 1

First experience: Representation of digital images (left) and operations between them (right)

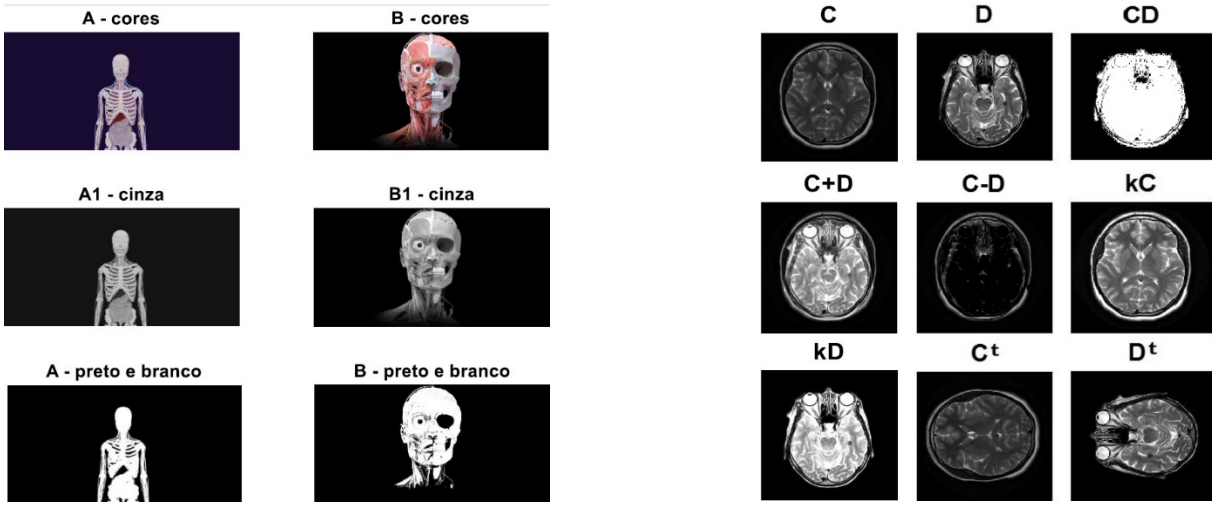
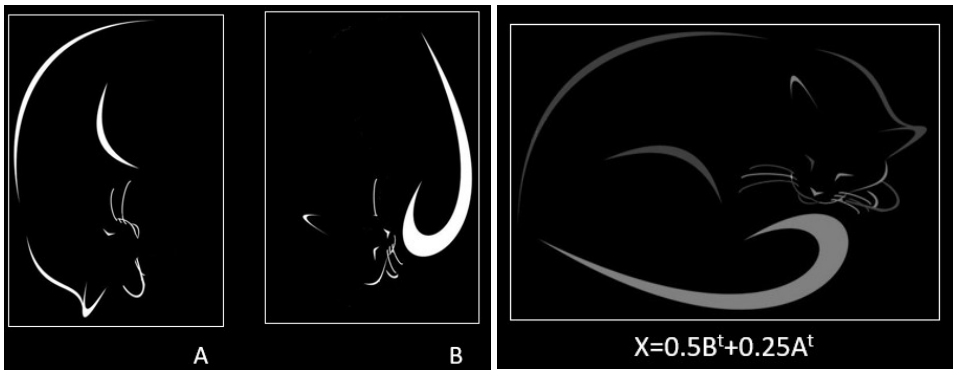


Figure 2

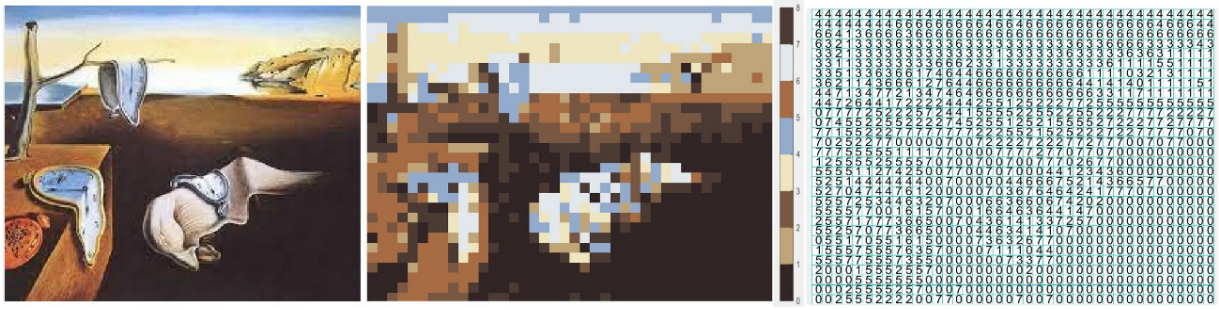
Second experience: Find the X matrix



"Paint by numbers" are boards with light markings to indicate the areas to be painted, each area having a number and a corresponding numbered paint to be used. This experience can be created by the student, considering the board as a matrix with a set of rows and columns where the numbers will be pasted according to the colours. The definition of matrix, the arrangement of numbers and their connotation with colours allow the student to have an idea of the mathematical representation associated with a digital image as can be seen in the example shown in Figure 3. The table with the numbers represents a matrix where each entry represents a colour.

Figure 3

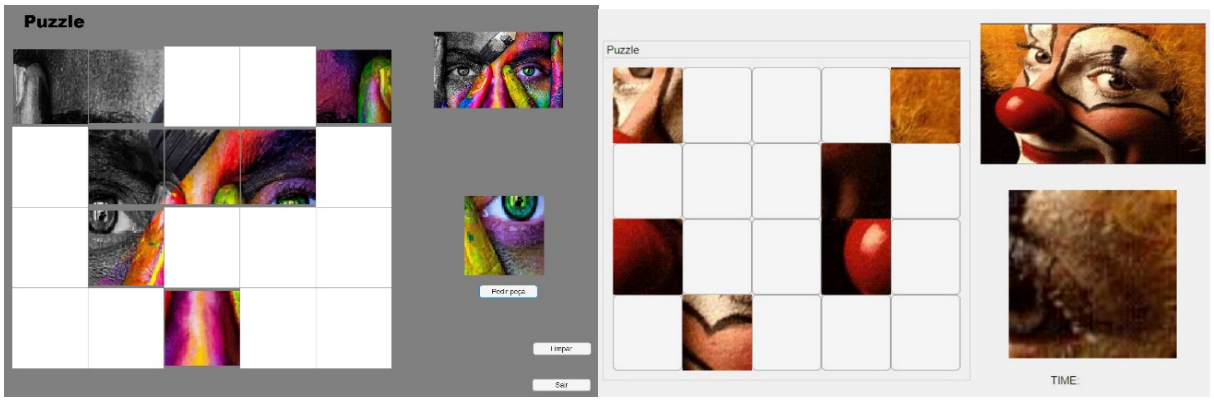
Third experience: Paint by numbers



A puzzle is a game where the player is expected to logically put together a set of pieces to arrive at the correct solution (final image). If the final image is considered a matrix, each tile consists of a position in a row or column of that matrix. Thus, students demonstrate the skills obtained on the positions of elements in a matrix, size of the matrix, resizing a matrix, type of matrix and random definition of a sequence of parts. Figure 4 shows two examples, created by students. Here each entry (tile) in the matrix is a piece of the puzzle that will be positioned in a row and column.

Figure 4

Fourth experience: Create a puzzle – two examples



Geometric transformations such as reflection, translation, rotation, and scaling can be defined by matrices. To apply geometric transformations to plane figures it is necessary to define a matrix with all the points of the plane figure and multiply it by the geometric transformation matrix. For example, a reflection on the x-axis is represented by the matrix $R_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$. To transform a figure consisting of its defined points in the columns of the matrix, it is only necessary to use a multiplication between matrices (Figure 5). In this experience, students learn to define and multiply matrices considering their properties and restrictions. It is also necessary to define the geometric figures through a set of points placed in matrixes. In this example, the matrices represent the connection points of geometric figures.

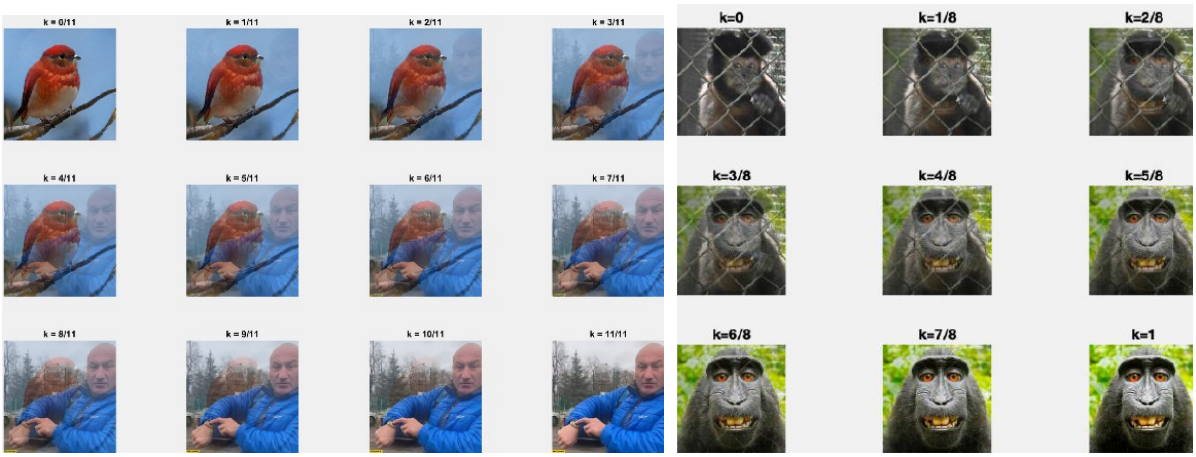
Figure 5

Fifth experience: Geometric transformations: reflection (left), scaling (centre) and rotation (right)

Linear combination is an important definition of vector spaces, one of the most abstract Linear Algebra subjects and where students have the most difficulty. The linear combination can be studied through a set of digital images by multiplying each one of them by a constant and adding all the products thus obtained. Students can visualize in a real activity the meaning of linear combination and its restrictions, as in the case of all matrices having the same dimension. In Figure 6 it is possible to observe a sequence of linear combinations between two images. Using two images with the same size A and B and applying the linear combination $(1-k)A+kB$, where $0 \leq k \leq 1$, it is possible to perform a transition between image A and image B. In Figure 6, on left the variation of k is $1/11$ and on the right $1/8$ so 12 and 9 images are shown respectively. It should be noted that the final representation can also be considered a matrix.

Figure 6

Sixth experience: Linear combination of images – two examples



RESULTS AND DISCUSSIONS

In the last 5 years, activities have been developed inside and outside the Linear Algebra classroom. Through the analysis of the classes and direct observation, it was concluded that the activities carried out by the experimental students were very important, namely in terms of their interest, curiosity, enthusiasm,

commitment, and motivation, as well as in terms of the positive influence they had. in the study of the syllabus. The evidenced results indicate that learning in a new digital image space favours the development of different skills in the learning context. These skills are the ability to work in a group, the ability to listen to the opinions of others, the capacity for self-learning, the ability to apply knowledge in practice, the analytical capacity, and the ability to synthesize information (Murillo-Zamorano, 2021). In addition, it will encourage students' self-learning, improve their e-skills, creative capacity, and practical skills to better adapt to the needs of society, where knowledge transfer generates development and growth and promotes innovation (Comesaña, 2022). In this way, the use of the new digital image space represents an educational tool that allows student learning, improving their academic performance.

CONCLUSIONS

For students to be proactive, it is necessary to adopt methodologies in which students get involved in increasingly complex activities, in which they must make decisions and evaluate the results, with support of relevant materials. In other words, they must experiment with new environments and active learning methodologies.

The connection between the digital image and Linear Algebra is a reality that can be explored by the teacher in the classroom context. Students who attend these classes with the support of the new space, are motivated and develop skills, abilities, values, and attitudes beyond the knowledge inherent to the contents of the curricular unit. The classes become pleasant, inspiring, creative, and learning is really achieved and, with that, the failure and evasion rates are reduced. With the experiences of these new ideas and teaching approaches, the teacher feels confident in the classroom which contributes to greater satisfaction in his work and allows to inspire his students in the learning process.

The new space of digital images as learning tool, is actually a space for the creation of knowledge focused on creative and motivating learning, as a tool for meaningful teaching of Linear Algebra in engineering courses.

In the future, this learning space will be continued, and other types of approaches will be investigated to demonstrate that the use of digital images as learning tools can help students learn skills and abilities. For example, it will incorporate some programming work to attract and retain the attention of higher-level students; in this way, they will have opportunities to explore Matlab. Other experiences will also be created that can be done in class or in homework, to stimulate students more effectively.

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